

Report for 2004HI57B: The Dynamic Effects of Native Versus Non-native Vegetation on the Ecohydrology of a Hawaiian Stream Valley

- Other Publications:

- Duarte, T. Kaeo; Charles F. Harvey, 2004, Optimal management of a coastal aquifer hydraulically linked to an inland high-level aquifer through a semi-permeable barrier, Working Paper, Water Resources Research Center, University of Hawaii, Honolulu, Hawaii.
- Duarte, T. Kaeo; Michela Robba; Charles Harvey, 2005, Optimal pumping strategies for a brackish, coastal pumping well, Working Paper, Water Resources Research Center, University of Hawaii, Honolulu, Hawaii.

Report Follows

Problem and Research Objectives

As populations increase and the demand for natural resources rises, so does the need for informed, sustainable resource management. In Hawai'i, one particular concern is that land-use change and invasive plant populations may be impacting groundwater recharge and thus freshwater supplies. While parcels of native forest are protected through the designation of water catchment areas, invasive plants threatening these forest parcels are believed to transpire more than their native counterparts or to alter the structure of Hawai'i's forests in a way that reduces recharge. However, these hypotheses have not been rigorously tested, and the hydrology of the typical Hawaiian watershed accounting for plant water uptake and growth has yet to be modeled. How do native forest communities facilitate infiltration, evapotranspiration, and runoff, and is there a significant difference between the water balance of a watershed dominated by native vegetation and that of a watershed dominated by introduced species? Does a native and perhaps more intact plant community sequester more groundwater than a non-native plant community?

Our research tests the hypothesis that vegetation change alters groundwater recharge by affecting the evapotranspiration (ET) and soil-moisture terms of the fundamental water-balance equation. Underlying this hypothesis is the belief that invasive species are faster-growing and have higher transpiration rates than relatively slow-growing natives. It is also thought that a non-native forest community might lack understory, resulting in increased evaporation due to increased wind speed and less humidity. Over time, this may lead to an overall decrease in ET and a net increase in runoff or leakage.

In order to better manage watersheds, we must understand how ecosystem processes work. Although Hawai'i's forest should be protected for biodiversity and cultural reasons alone, it should also be protected from the effects of changing forest communities that can have adverse ecohydrological impacts on the watershed. Is invasive species management a worthwhile venture, or should we let invasion run its course? We hope to collect the data and construct a model to rigorously analyze and predict the effects of changing forest communities on water supply in Hawai'i.

Methodology

To address the question of how different forest communities affect the local water balance, we are collecting data at two sites in South Kona, Hawai'i, and are constructing models of climate-soil-vegetation dynamics at these sites. Our study involves both ecological and hydrological methodologies. The site at Kahauloa is dominated by native canopy trees and understory, whereas the site at Honaunau is dominated by non-native tropical ash and eucalyptus trees. These two sites were selected to eliminate variation in climate and soil type between sites and to therefore isolate ecohydrological effects due to vegetation differences. They were also chosen for their relatively flat grade and lack of observed surface runoff, which helps simplify the model. Both are located at the same elevation, and preliminary rainfall and radiation data indicate that they are affected by the same climatic factors.

The focus of this study is primarily to determine the effects of vegetation on ET. Both ecological and hydrological methods and equipment are used toward this end. The primary tasks can be summarized as follows:

1. Plots that best represent the average native and non-native forests at the same elevation were chosen for study.
2. Transects were set up around the stations and assessments of local plant species composition made.
3. Evapotranspiration stations were set up at each of the two sites to measure solar radiation, air temperature, relative humidity, rainfall, wind speed, wind direction, and soil moisture. Using this data, potential ET is evaluated with the Penman–Monteith equation, a well-known and established equation in hydrology.
4. Pairs of soil-matric-potential blocks and TDR soil-moisture-content probes were installed at each station. The data will be used to define a soil-moisture-retention curve that can be used to estimate infiltration rates.
5. Studies of xylem sap flow and leaf gas exchange will be independently conducted on the dominant tree species at each of the two sites to estimate transpiration (in FY 2005).
6. Net infiltration into the aquifer will be computed by subtracting ET from rainfall and by using the botanical methods described in task 5 (in FY 2005).
7. Statistical analyses will be done to determine uncertainty in the measurements, and native forest and non-native forest ET and infiltration will be compared (in FY 2005).

Principal Findings and Significance

Data on temperature, humidity, net solar radiation, wind speed and direction, and soil moisture have been collected since May 2004. Although data from more sites are needed to investigate possible spatial heterogeneities, the collected data have yielded interesting preliminary results. The findings are listed below:

1. In agreement with our original hypothesis, wind speeds are higher by 400% in the non-native forest. This result implies that, with all other parameters held constant, evaporation and transpiration in the non-native forest should be much higher.
2. Temperatures are lower in the non-native forest, which agrees with our observation of higher wind speeds and hence more evaporation.
3. Humidity is slightly higher in the native forest.
4. Soil moisture is higher in the native forest, but more measurements need to be taken and more calibration to the local soils needs to be done before any serious conclusion can be reached.
5. Comparative analysis of rainfall and soil-moisture response at the paired native versus non-native sites indicates that the two sites are indeed responding to the same climate regime. This result is critical to our study as it validates our assumption that forest-scale climate and elevation differences have been effectively eliminated between the two sites. This allows us to focus our attention on how two different types of forest affect local soil-moisture and infiltration conditions, if at all.

The next task to be completed is the xylem sap flow and gas exchange work. Once that work is completed we will be able to show (1) how ET varies between a native rainforest and a non-native rainforest in Hawai'i and (2) how infiltration differs as a result of the different forest communities.